Changes in fishery resources and reef fish assemblages in a Marine Protected Area in the US Virgin Islands: the need for a no take marine reserve

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ABSTRACT

Fishery resources have declined and reef fish assemblages have changed over the last 30-40 years in the US Virgin Islands (USVI), even within a Marine Protected Area, Virgin Islands National Park (VINP). Groupers and snappers are now far less abundant, the proportion of herbivorous fishes has increased, individuals of many fish species are smaller, and spawning aggregations have been decimated. The national park is not a refuge for reef fishes. Relative abundance, species richness, and biomass of fishes in visual samples, and the species composition and number of fishes in traps are similar inside and outside VINP. Lobsters and conchs have decreased in abundance and/or size, and conch density is no greater within VINP than outside. Although habitat degradation has undoubtedly played a role, heavy fishing pressure has greatly contributed to the observed changes. No-take marine reserves, such as the recently established national monuments in the USVI, offer hope for recovery of fish assemblages and associated habitats.

Keywords Coral reefs, Fishery declines, Marine reserves, Reef fishes.

Introduction

In the Caribbean, natural and human stresses have caused degradation of marine ecosystems and declines in associated fishes and invertebrates (Hughes 1994, Aronson and Precht 2000). In the USVI, overfishing, major storms, and coral diseases are most responsible for declines in fishery resources, changes in reef fish assemblages, and degradation of marine ecosystems. Here we synthesize information on fishery resources and reef fish assemblages in the USVI, with focus on a Marine Protected Area, VINP on St. John. Fishery resources and associated benthic habitats within this national park are exhibiting the same trends as observed throughout the USVI. We suggest that overfishing is the primary reason for the observed declines in the fisheries and changes in fish assemblages and argue for greater protection, specifically, that fishing should be eliminated within the park.

Tracking changes in reef fish assemblages and abundance of fishery resources is very challenging and requires long-term data, over appropriate temporal and spatial scales. Reef fish abundances vary notoriously, e.g. reflecting variations in recruitment. Lobsters and conchs have very patchy distributions. Furthermore, most marine organisms have planktonic larvae that settle in habitats far from their release site. Local assemblages may reflect the influence of local factors as well as other factors operating hundreds of kilometers "upstream" (Leis 1991, Jones et al. 1999, Swearer et al. 1999, Cowen et al. 2000). Our assessment of the current status of the fishery resources in the USVI, and within VINP, is based on qualitative and quantitative information from historical and recent studies, including some of the longest research projects in the Caribbean (e.g. Beets 1996, 1997, USGS unpublished data).

VINP was established in 1956 with marine portions added in 1962. The park consists of 2,947 hectares (ha) of land (about 56% of the 48 km^2 island) and 2,287 ha of surrounding waters. Commercial fishing is prohibited in the park. Taking of fishes or other marine life is also prohibited except for personal use with rod and line or with traps of "conventional Virgin Islands design" and 20 ft seine nets. There is a limit of two conchs (*Strombus gigas*) and two lobsters (*Panulirus argus*) per person per day. Territorial government fisheries regulations also apply in VINP, including trap mesh size restrictions. Trunk Bay (c. 21 ha) within VINP is technically a no-take area where fishing is prohibited; however, this area is not a significant reef fish refuge because of the minimal reef habitat and extensive recreational use (as many as 1000 people per day).

Characteristics of the fishery

In the USVI, about 180 species of reef fishes are harvested, in addition to queen conchs (*Strombus gigas*) and lobsters (primarily *Panulirus argus*) (Caribbean Fisheries Management Council 1985). A recent report lists 180 commercial fishers from St. Croix and 182 from St. Thomas-St. John (Tobias 1997). The primary fishing gears (traps, followed by hook and line, and nets) have not changed greatly since the 1930's (Fiedler and Jarvis 1932).

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Small-scale commercial fishers and those who fish for personal use set few traps or use only handlines, whereas, large-scale commercial fishers set several trap lines with over 20 traps per line. Though prohibited, commercial fishing occurs in the park (Garrison et al. 1998, NPS records). When the park was first established, fishers usually set only a few, smaller traps and primarily fished in nearshore areas (Randall 1963). The small number of fishers from St. John (about 30) is not a reliable indicator of fishing pressure because fishers from St. Thomas and the British Virgin Islands also fish off St. John (Garrison et al. 1998, Pomeroy 1999).

Changes in fishery resources and reef fish assemblages

Significant changes in reef fish assemblages and in fishery resources in the USVI have occurred over the last 30 to 40 years. Evidence suggests that heavy fishing pressure is responsible for most if not all of these changes. The documented changes include: loss of grouper spawning aggregations, declines in proportional catch of groupers and snappers, and decreases in the abundances and average sizes of fishes. Also, large predatory fishes are now very rare in visual samples.

In the 1960s, large predatory fishes, like groupers and snappers, declined in landings with increased fishing effort. Following the increased demand for fish with the tourism boom and technological changes in the fishery (larger boats, engines, improved gear), fishers began to set more traps, to target species like groupers and snappers, and to fish farther offshore.

By the 1970s, spawning aggregations for yellowfin grouper (*Mycteroperca venenosa*) and mutton snapper (*Lutjanus analis*) apparently were decimated and their landings declined. The Nassau grouper (*Epinephelus striatus*) spawning aggregation was extirpated (Olsen and LaPlace 1978). In the early 1970s fishers reported catching up to 1000 kg of this species on the aggregation site off St. Thomas during the two-month spawning period. By the mid 1970s, catches on the site had become extremely low (Olsen and LaPlace 1978). Following the decline of large grouper species, fishers targeted the red hind (*Epinephelus guttatus*), which began to decline in landings as well.

As fishing effort increased, catch composition changed, CPUE declined, and many species were overexploited (Appeldoorn et al. 1992, Beets 1997). The number of fish traps in use in the USVI increased greatly from about 5,000 to over 15,000 between 1978 and 1987, while the annual catch per trap decreased significantly from about 350 lbs/yr in 1979 to 100 lbs/yr in 1987 (Appeldoorn et al. 1992). Between 1985 and 1990, mean capture size of several species decreased (Appeldoorn et al. 1992). Concerns over declines in fish abundance led to the preparation of a Fishery Management Plan (FMP) for federal waters off Puerto Rico and the USVI in 1985, with more stringent amendments (CFMC 1985, 1990, 1993).

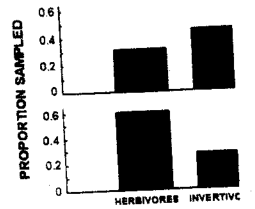
St. John and Virgin Islands National Park

Observations from the 1950s-1960s suggest that fishing was already changing the reef fishes around St. John (Randall 1963). John Randall recorded his observations within VINP (Randall's field notes, 1958-1961) : "Impressed by the lack of food fishes such as groupers and snappers. --- I saw only two small Nassau groupers, one tiger rockfish, and no other groupers. It would seem that there has been considerable fishing effort. This was confirmed by Charles Adams, the park naturalist." Although many species of fishes were becoming scarcer in the 1960s, they were undoubtedly more abundant than they are now. For example, Randall speared over 100 Nassau groupers around St. John over 2.5 years (1958-1961), and this species was the most abundant grouper in his samples. In addition, he tagged 124 adult Nassau groupers in a single bay during a study between February 1959 and June 1961 (Randall 1961). In contrast, during a 5-year annual monitoring project (1994-1999), only 37 Nassau groupers were observed in 32 sample plots (each 5000 m^2) on four reefs around St. John, (Beets, unpublished data). Other fish species that were noted as common by Randall, such as midnight parrotfish and spadefish, are now rarely seen.

A recent comparison of trap data between 1982-3 and 1993-4 showed alarming changes in trophic composition (Beets 1997): the proportion of herbivorous fishes increased and the proportion of large predators (groupers and snappers) decreased (Fig. 1). The average size of fishes in all trophic groups was smaller in the 1993-94 samples (Fig. 2). Four species of groupers caught in traps during 1982-83 were not trapped in 1993-94 (although they have been observed occasionally in visual samples from 1988-2000). In contrast, in the same bay over two decades earlier, poison stations showed that groupers were the second most abundant family present (Randall 1961).

Even relatively small fishing effort may have profound effects. For example, an experimental trapping study in 1993-1994 showed that a small number of traps fished over six months caused significant declines in several trophic groups (Fig. 3, Beets 1996, see also Coblentz 1997).

Other recent studies also show a scarcity of predatory fishes and an increase in relative abundance of herbivorous fishes around St. John. Garrison et al. (1998) recorded only six Nassau groupers out of a total of 1,340 fishes observed in traps set by fishers (1992-1994), and herbivorous surgeonfishes were dominant. In 1994, Wolff et al. (1999) observed no Nassau groupers in 159 visual samples, and this species comprised less than 1% of the trap catch (n = 297 trap hauls). Three herbivorous species accounted for over 50% of the individuals recorded in both trap and visual samples.



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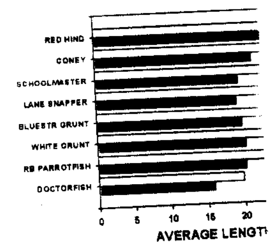

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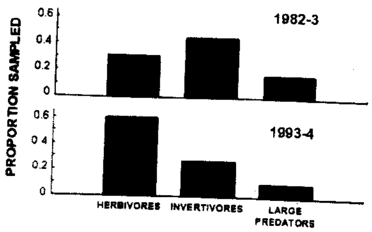

Fig. 1 Comparison of the proportion of fishes in trap catches during two six-month sampling periods around a single reef in VINP, 1982-3 and 1993-4. Herbivores were primarily parrotfishes and surgeonfishes; invertivores were primarily grunts and porgies; large predators were primarily groupers and snappers.

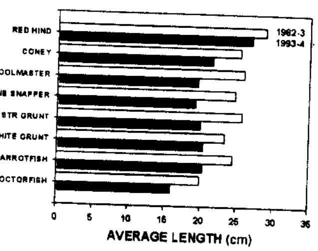

Fig. 2 Average length of fishes in fish trap samples taken during two six-month periods around a single reef in VINP, 1982-3 and 1993-4. Most species with adequate sample sizes had smaller average size in 1993-4, and these species represented the most common caught in different trophic groups: groupers – red hind (*Epinephelus guttatus*), coney (*E. fulvus*); snappers – schoolmaster (*Lutjanus apodus*), lane snapper (*L. synodus*); mobile invertebrate feeders – bluestriped grunt (*Haemulon sciurus*), white grunt (*H. plumieri*); herbivores – redband parrotfish (*Sparisoma aurofrenatum*), doctorfish (*Acanthurus chirurgus*).

Fish assemblages do not differ inside and outside the park. Visual samples from St. John reefs (1989-1994) demonstrated no significant differences in number of fishes, number of species or biomass of fishes per sample (Figs. 4, 5). In 1993, the number of fishes caught per trap haul in fish trap samples inside and outside the park was not significantly different (n = 145 trap hauls, t-stat: 1.24, p = 0.22; Beets 1996). Garrison et al. (1998) found no significant differences in the species composition or number of fishes observed in traps inside vs. outside VINP.

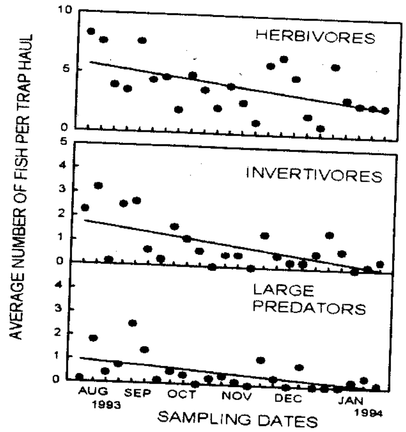

Fig. 3 Declines in fish trap catches during six months of sampling around a single reef in VINP, 1993. Eight traps were hauled weekly on ~10,000 m^2 fringing reef. Large predators were primarily groupers and snappers. Regressions were significant for these three trophic groups ($p < 0.05$). Modified from Beets 1996.

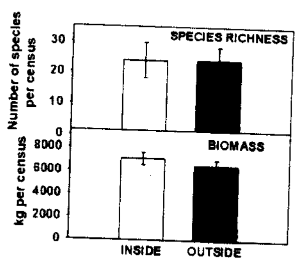

Fig. 4 Average species richness and biomass per visual census of fishes sampled inside and outside the boundaries of VINP, 1989-1994. No significant differences observed for either parameter. Error bars re-present one standard deviation.

Conchs and lobsters

Randall (1964) observed hundreds of conchs in the 1960s. Schroeder (1965) mentioned "conch by the thousands in Salt Pond Bay". Such numbers are not seen today. In spite of a moratorium from 1988-1992 in St. Thomas and St. John, additional regulations in 1994, and a limit of two conchs per person per day for VINP waters, conch abundance in general appears to be decreasing, and conch density is not significantly different within and outside the park (Friedlander 1997). Although anecdotal information suggests large declines in inshore abundance of lobster around St. John, few investigations have been conducted on this important resource. Wolff (1998) noted that lobster densities for 4 sites around St. John in 1996 averaged only 5/ha compared to 19.4/ha at 89 sites around the island in 1970. Data suggest average size of lobsters declined within the park since 1970.

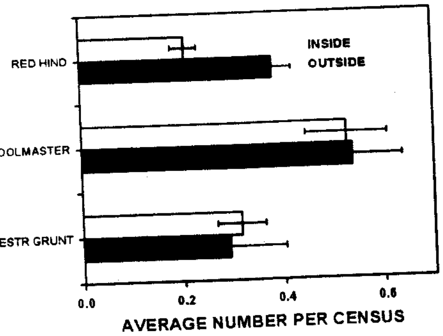

Fig. 5 Mean abundance of three fish species in visual census samples on reefs inside and outside VINP, 1989-1994. These species were the most abundant fishes sampled in their respective families: grouper – red hind (*Epinephelus guttatus*); snapper – schoolmaster (*Lutjanus apodus*); grunt – bluestriped grunt (*Haemulon sciurus*). Error bars represent one standard deviation.

Habitat degradation

The effects of overfishing are difficult to separate from the effects of habitat degradation, although deterioration of mangroves, seagrass beds and reefs has undoubtedly played a role in the decline of fisheries and changes in reef fish assemblages. All of these ecosystems function as critical nursery areas and provide habitat for adult fishes and other organisms. Most marine organisms rely on several habitats at different ontogenetic stages, and degradation of any habitat can have serious detrimental effects. Studies show fish species richness and abundance are positively correlated with reef spatial complexity, habitat type/quality, and the amount of live coral (Hixon and Beets 1993, Friedlander and Parrish 1998, Wolff et al. 1999), suggesting that coral mortality and damage to reef structure can affect reef fish assemblages. Hurricanes can have very significant effects on local fish assemblage structure (Kauffman 1983, Walsh 1983).

Since 1979, nine hurricanes have passed over or near St. John. Hurricanes David (1979) and Hugo (1989) caused severe destruction (Rogers et al. 1982, Beets et al. 1986, Rogers et al. 1991). Coral cover has still not recovered substantially in the most damaged areas, and macroalgae are often very abundant (e.g. Rogers et al. 1997). The level of herbivory by sea urchins and fishes has been too low to control the macroalgae that inhibit settlement and survival of coral recruits and growth by existing coral colonies (Rogers et al. 1997).

In addition to hurricanes, physical damage to coral reefs from boat anchors and groundings has been severe, especially within the park on St. John (Rogers and Garrison in press, Link 1997). Coral bleaching and diseases (especially white band disease and plague type II) have also taken a toll on the reefs (Gladfelter 1982, USGS unpublished data). Development on St. John, outside the national park and in private "inholdings", has been accelerating dramatically, and increased runoff from the island's steep hillsides is also a serious concern (CH_2M Hill 1979, Anderson and MacDonald 1998).

The extent and density of seagrass beds around St. John have declined since the late 1950s, largely because of hurricanes (L. Muehlstein, unpublished data) and anchor damage (Williams 1988). A 1959 map indicated extensive coverage by seagrass beds around the island (Kumpf and Randall 1961, Randall 1965). Hurricanes in 1989, 1995 and 1999 caused major "blowouts" (scoured depressions in the bottom) in seagrass beds, and analysis of aerial photographs (1962-1983) showed declines in several bays (L. Muehlstein, unpublished data). Large changes in the average densities of both *Thalassia testudinum* and *Syringodium filiforme* were documented during a 10-year monitoring project in Great Lameshur Bay (1990-1999; Muehlstein and Beets 1999).

Mangrove communities have not been studied extensively in the Virgin Islands, although they are important nurseries for reef fishes (Boulon 1992). The mangroves around St. John are primarily narrow fringes around protected bays and salt ponds. Several hurricanes and a severe drought in 1994-1995 damaged many mangrove forests in the USVI.

Conclusions

In the USVI, there is clear evidence that overfishing has resulted in fishery declines and changes to reef fish assemblages. Degradation of benthic habitats has undoubtedly contributed to these changes, but the signs of overfishing appeared before the extensive loss of habitat from coastal development, coral diseases, hurricanes, and other stresses. Loss of spawning aggregations, decreases in average size of fishes, and dramatic declines in fish abundance point to fishing as the causative agent. Detrimental effects of fishing on reef fish assemblages and habitats are well documented (Koslow et al. 1988, Russ 1991, Hughes 1994, Jennings and Polunin 1996, Beets 1997, Hixon 1997).

This synthesis of research in the USVI documents the failure of federal and territorial regulations to protect reef fishes. Furthermore, no evidence exists that reef fish species abundance and biomass *within* VINP differ significantly from those *outside* the park boundaries. For example, no significant differences were found between the relative abundance, species richness, and biomass of fishes in visual samples collected inside and outside of VINP. Likewise, species composition and number of fishes observed in traps inside and outside the park were similar. Lack of enforcement has no doubt played a role (see Garrison et al. 1998).

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No-take marine reserves, such as the national monuments established in January 2001 in the USVI, offer the best (and probably the last) hope for recovery of the benthic resources and the associated fishes (Bohnsack 1996, Bohnsack and Ault 1996, Murray et al. 1999). In general, conventional regulations for managing fisheries have not worked, especially for multi-species fisheries such as those associated with coral reefs.

During the past decade, the benefits of establishing no-take marine reserves have been theoretically and empirically documented (Bohnsack 1996, Murray et al. 1999). For example, marine reserves offer the potential for increases in abundance of piscivorous fishes (predators), such as some groupers and snappers, and increases in the mean sizes of piscivorous fishes.

A local, successful attempt to reverse the decline in red hinds demonstrated the benefits of eliminating fishing. In response to the loss of the Nassau grouper spawning aggregation south of St. Thomas and declining trends for red hind, a federal seasonal closure was enacted at the spawning site in 1990. Subsequently, increased average fish length and a less skewed sex ratio were documented (Beets and Friedlander 1999). In 1999, the closed area was designated a permanent marine reserve (Marine Conservation District) with all fishing and anchoring prohibited (FR 64 No. 213).

Although we recognize that marine reserves will not protect resources from natural disturbances, the urgent need for better protection of the resources, even those within marine protected areas such as the national park in the USVI, is irrefutable.

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Regula
ar

The study of population regu patterns in the field. We ana top-down and bottom-up re recruitment variance is propa by absorbing recruitment vari adult fish biomass through t counting fish alone, but requ human-created clines of rec regulation on coral reefs.

Keywords Fish, Regulation, Bott Predation

Introduction

Population regulation is know population to persist (Haldane 19 of that regulation is often un population regulation on the co where variability consistently obs of noise. In the field, the regulatory processes, such as der or competition, is difficult beca environmental stochasticity (Ha Hughes 1988, Caley et al. 199 directly studying regulation wit experiments (e.g. Doherty 1983, Forrester 1995, Beets 1997, Hix look for evidence of regulatory p data collected on natural reefs.

A well-defined series of pre interpret the growing literatu population dynamics. To date, fe made regarding the large-scale processes on fish populations Anneville et al. 1998, Chesson 1 effected in a number of ways, w having qualitatively different im demographics.

Both top-down and bottom-u population bounded with an i equilibrium. Bottom-up control type of regulation by a limiting r The mechanism of regulation is r of the actual resource but rather resource. Some relevant examp in the marine environment ar amongst herbivorous fish (e.g. Thresher 1976) and space limit Levin and Paine 1974, Roughgar

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